Fixing the Broken Academic Career Pipeline

Lifelong Learning in the Biomedical Sciences

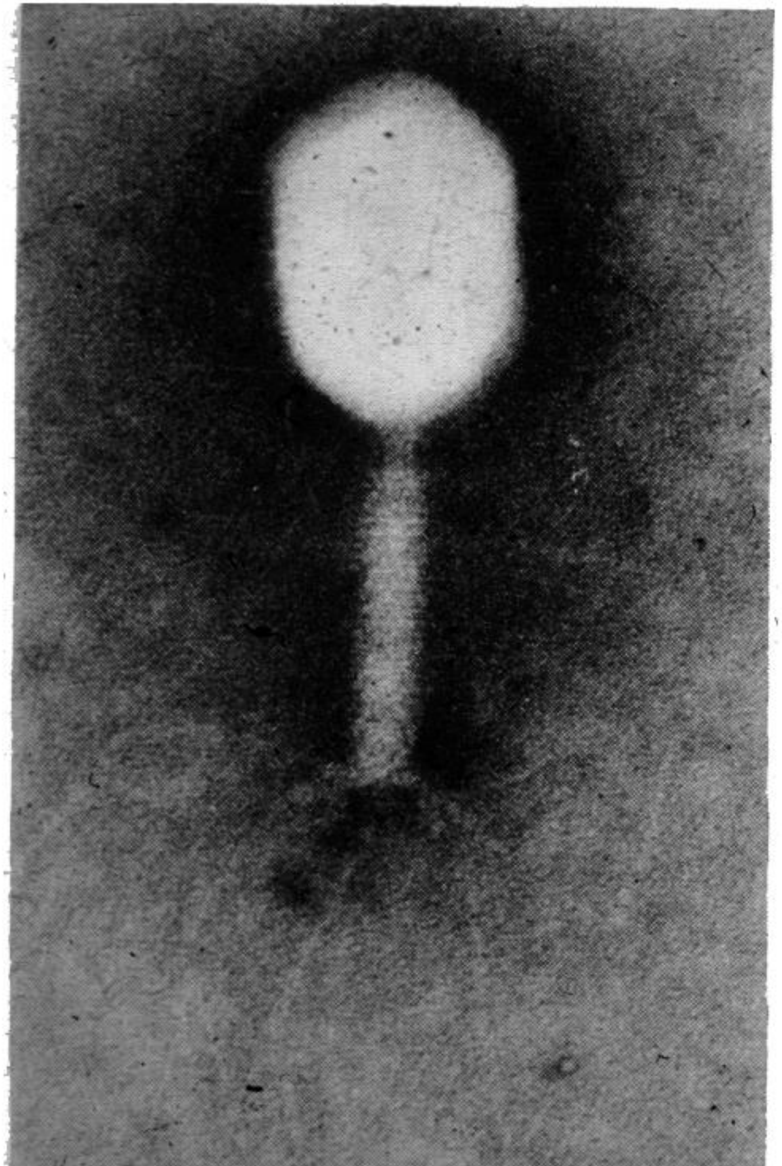
EMBL; Heidelberg

July 5, 2016

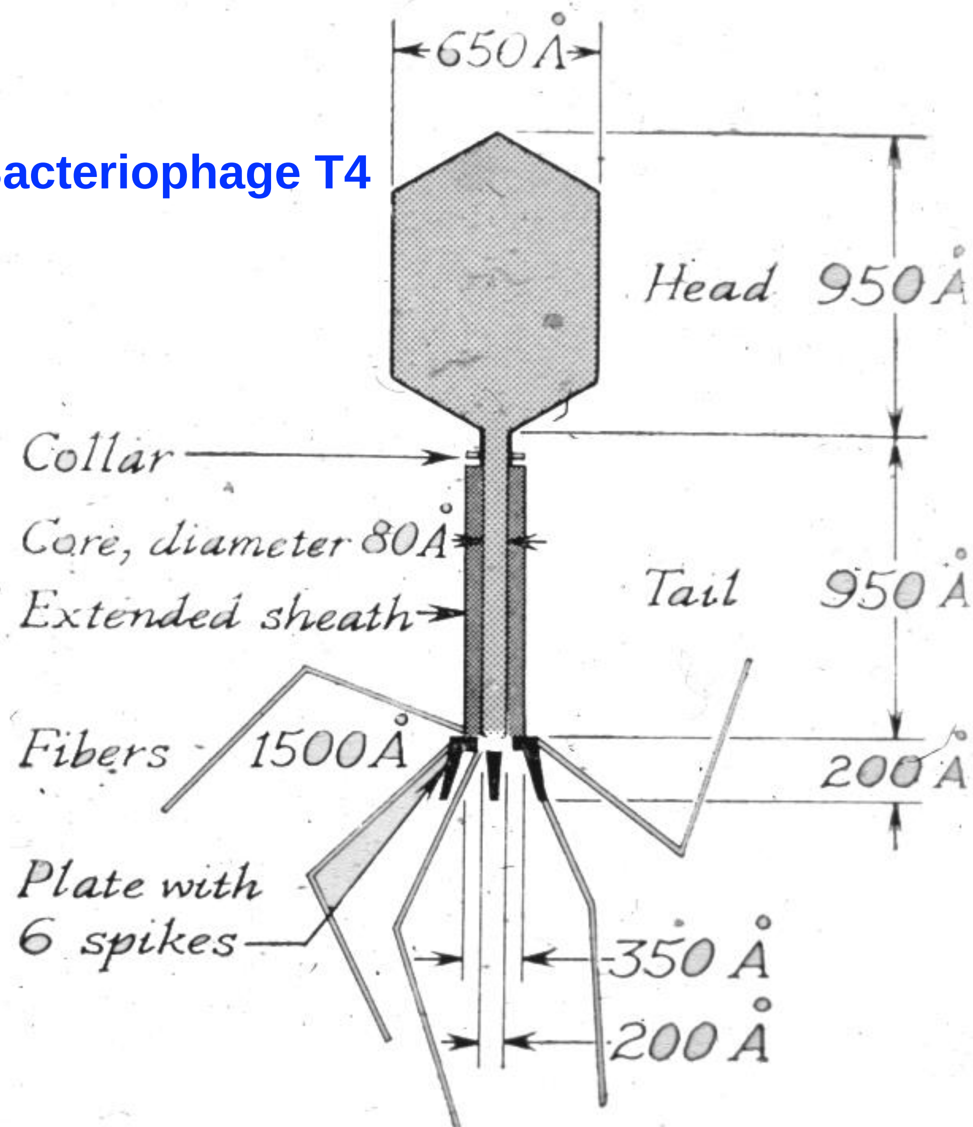
Bruce Alberts
Professor of Science and Education
University of California, San Francisco (UCSF)

A small bit of personal history

From 1966 - 1993, I was a research scientist using this virus that infects bacteria to study the mechanism of heredity (DNA replication)



Bacteriophage T4



After 27 years running a research laboratory, I was suddenly selected as the full-time president of the US National Academy of Sciences

A sudden shift from science to science policy

The National Academies of

SCIENCES • ENGINEERING • MEDICINE

My **education** in Washington, DC

1993 to 2005

The central lesson from my 12 years in Washington

It is critically important that science, science teachers, and scientists, achieve **a much higher degree of influence** throughout both their nations and the world.

SCIENCE FOR POLICY

Why scientific judgments are crucial for all policymakers

- Science has allowed humans to gain a deep understanding of the natural world.

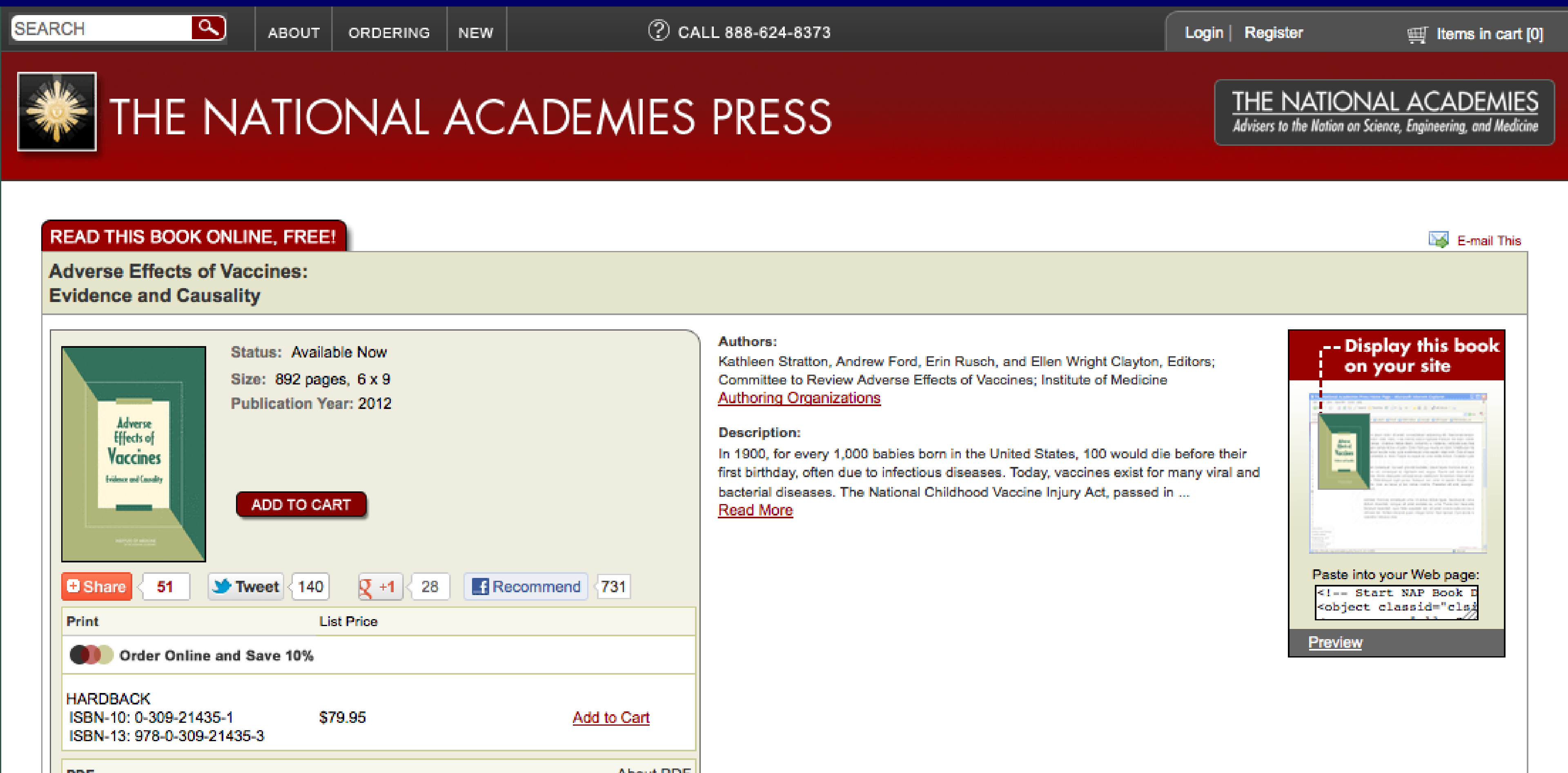
- In many cases, we can therefore predict the effects of current actions on the future.


I see a major increase in global warming!
SCIENCE

Science to underlie policymaking

www.NAP.edu

Free full text of **5000 books** on-line, accessible through a powerful search engine.

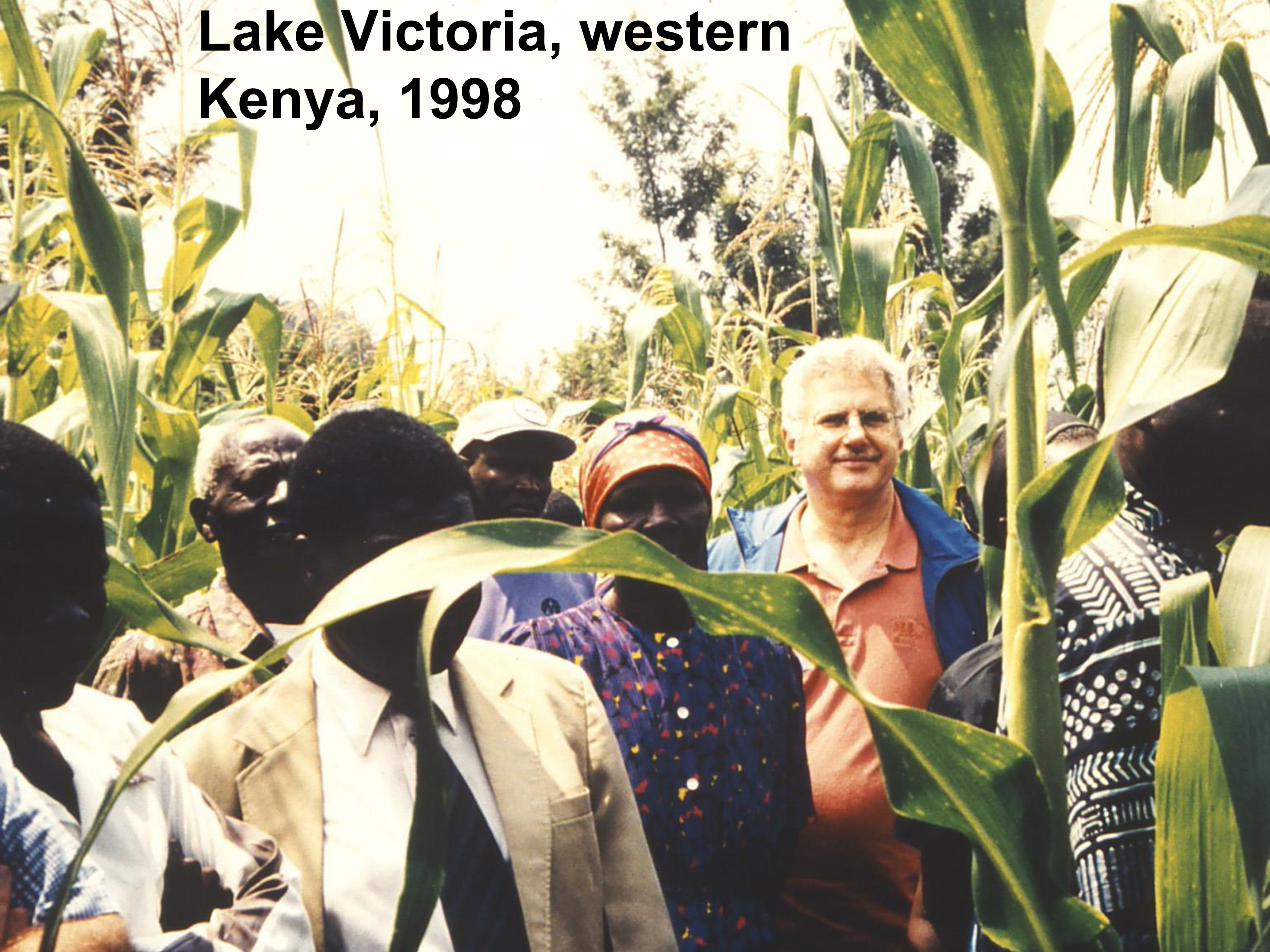


POLICY FOR SCIENCE

An important part of my education at the Academy was recognition of the critical importance of

Science for all !

Lake Victoria, western Kenya, 1998



My final issue as Editor-in-Chief of *Science* magazine

May 31, 2013

Based on an April 2013 trip to India with Science news staff

Science for All

With 400 million people earning less than $1.25 per day, India is home to a staggering one-third of the world's poor. Can scientists do more to lift people out of poverty?

CHENNAI, INDIA—In March 2012, Ashok Jhunjhunwala invited 45 young hotshots in India's electronics industry to this southern Indian city to brainstorm on a challenge: Could they design a tablet computer with Internet connectivity that would sell for 2500 Indian rupees—about $50—and still allow their companies to turn a profit on the device? To Jhunjhunwala, an electrical engineer here at the Indian Institute of Technology (IIT), Madras, it wasn't merely the fortunes of India's Silicon Valley that hung in the balance. India's future was at stake.

India has made strides in extending education to all strata of society. According to the Ministry of Human Resources Development, in 2010, 50% of children attended school through grade 12—up from 37% just 8 years ago. Equality is taking root in higher education as well. "The poorest children are getting into engineering colleges. That was inconceivable a decade back," says Jhunjhunwala, who serves on a science advisory council to Prime Minister Manmohan Singh. But India is failing, Jhunjhunwala says, in what it offers up to those young minds in the classroom. "We have made zero progress, even negative progress, in the quality of education," he asserts. Steering away from rote instruction and raising the bar, he says, "is our biggest challenge."

Jhunjhunwala didn't expect a cure-all from the computer jocks he coaxed to Chennai. But he knew that an inexpensive tablet, purchased en masse by the government and distributed to students, would be a powerful teaching aid. Two previous attempts had not lived up to their promise, and half the companies represented in the room, Jhunjhunwala knew, "were dead opposed to the idea" of a cheap tablet. It was hard to erase memories of the first cut-rate handheld alternative to laptops developed in India: the Simputer, which flopped a decade ago. The industry needed a reboot. But after huddling with the group all day, Jhunjhunwala recalls, "we felt confident that we could do something."

Unlike in past efforts, competition is the name of the game this time. As *Science* went to press, a dozen companies were racing to refine prototypes of a $50 tablet. These are undergoing dozens of performance tests here at IIT Madras's research park. Based on the benchmarking outcome, the Indian government is considering making an initial purchase this fall of 5 million tablets from the five top-performing manufacturers;

CREDIT: PALLAVA BAGLA

What have I learned

Science and technology can make a major difference for national development through many interventions.

But most of these are much too fine-grained for outsiders to expect to be able to solve other nation’s problems.

For every nation, strong institutions for science, health, and technology are key

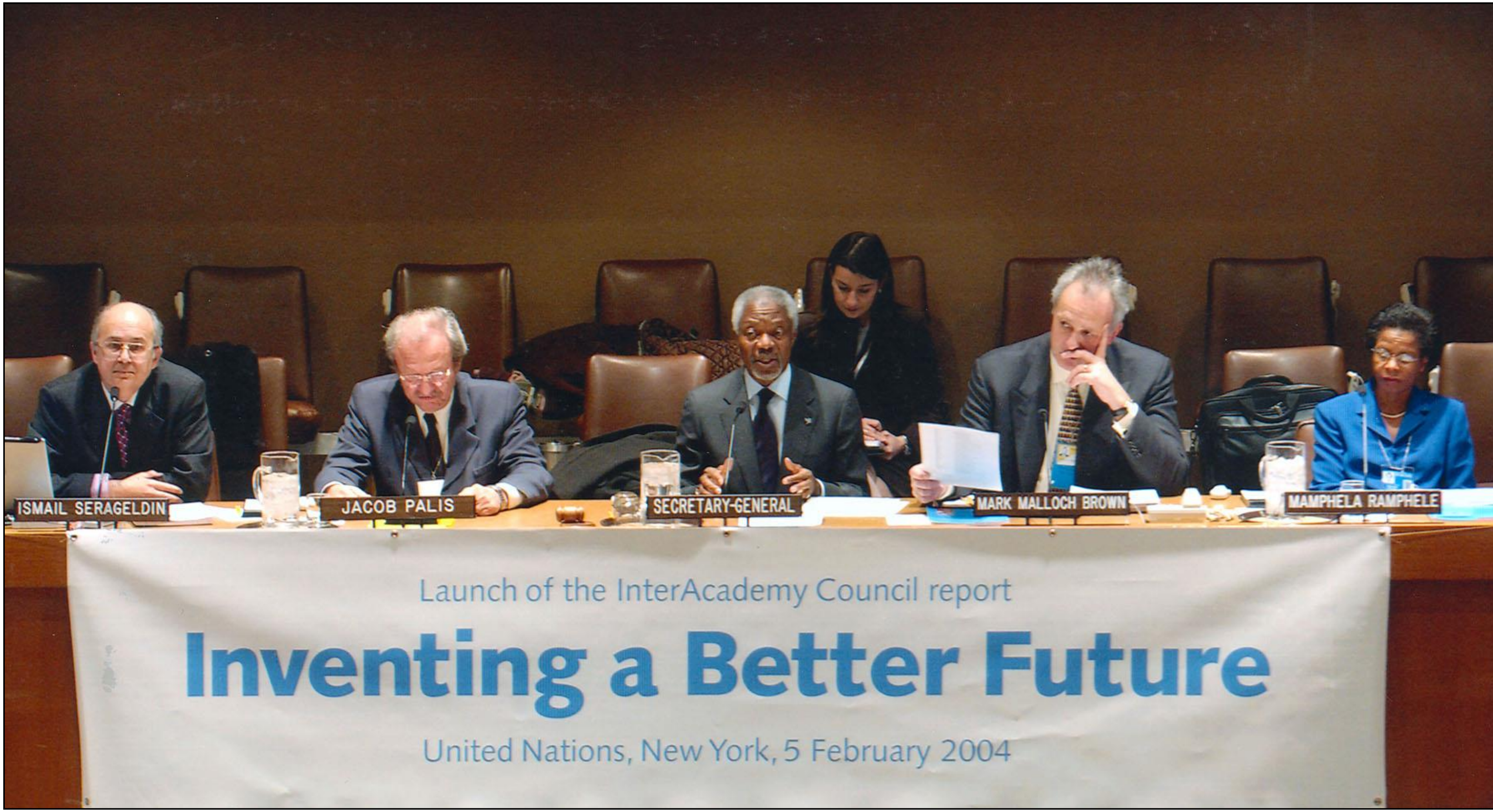
- Scientists are unlikely to be effective in either their work or in guiding the decisions made by their nations without strong institutions to support and harness their efforts.

- To develop, harness, and retain the talent needed in every nation, **building and supporting effective merit-based institutions for science, health & technology must become a key goal for development**.

The promise of world science collaboration

The first InterAcademy Council Report:

A Guide for S & T Capacity Building



A SCIENTIFIC TEMPER

Of equal importance, we also need much more of the creativity, rationality, openness, and tolerance that are inherent to science --- what Indian Prime Minister Nehru called a "**scientific temper**" -- for the success of every nation

Values of Science

- Honesty
- Generosity
- A strong demand for evidence, with openness to all ideas and opinions irrespective of their source

My favorite quote

"The society of scientists is simple because it has a directing purpose: to explore the truth. Nevertheless, it has to solve the problem of every society, which is to find a compromise between the individual and the group. It must encourage the single scientist to be independent, and the body of scientists to be tolerant. From these basic conditions, which form the prime values, there follows step by step a range of values: dissent, freedom of thought and speech, justice, honor, human dignity and self respect.

Science has humanized our values. Men have asked for freedom, justice and respect precisely as the scientific spirit has spread among them."

Jacob Bronowski, Science and Human Values, 1956

SPREADING THE SPIRIT OF SCIENCE

Ambitious goals: some strategies

Strategy 1, education:

To generate a scientific temper for each nation, we need to **redefine** what is meant by “science education” at all levels, from age 5 through college.

The image we want for science

A Disturbing Recent Fact

An 8-year old US student comes home from school and tells his mother:

"Now I get it, **science is just like spelling; you just need to memorize it and it doesn't make any sense**."

What science should look like in school


12 year-old students in San Francisco

What 5 year olds can do

1) Put on clean white socks and walk around school yard.
2) In class, collect all black specks stuck to socks and try to classify them: which are seeds and which are dirt?
3) Start by examining each speck with a 3 dollar, plastic “microscope”.
4) End by planting both those specks believed to be dirt and those believed to be seeds, thereby testing their own idea that the regularly shaped ones are seeds.

To remove a major barrier to progress at the precollege level, science education at the college level must change

An Important Barrier to Progress

The traditional lecture format allows a single professor to “batch process” many hundreds of students through an introductory science class.

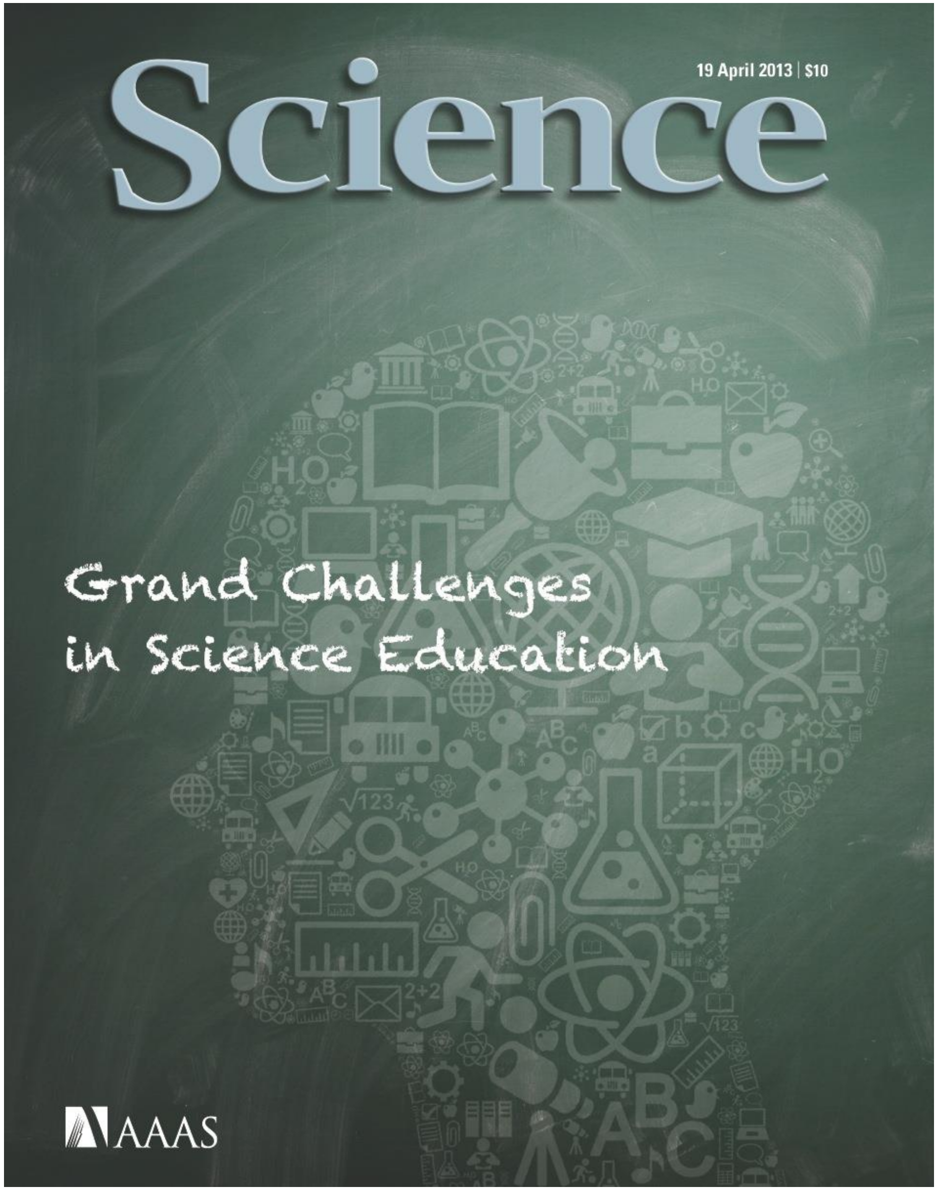
Can we create much better alternatives without a great increase in cost?

Interactive, “no lecture” science classroom
University of Minnesota

(22 tables, each with 9 chairs, two computers, overhead screen)

Active learning in college biology class

Science magazine has been trying to help: special issues on education



April 19, 2013

24 winners of a college science prize were published in 2012 and 2013 ("IBI Prize")

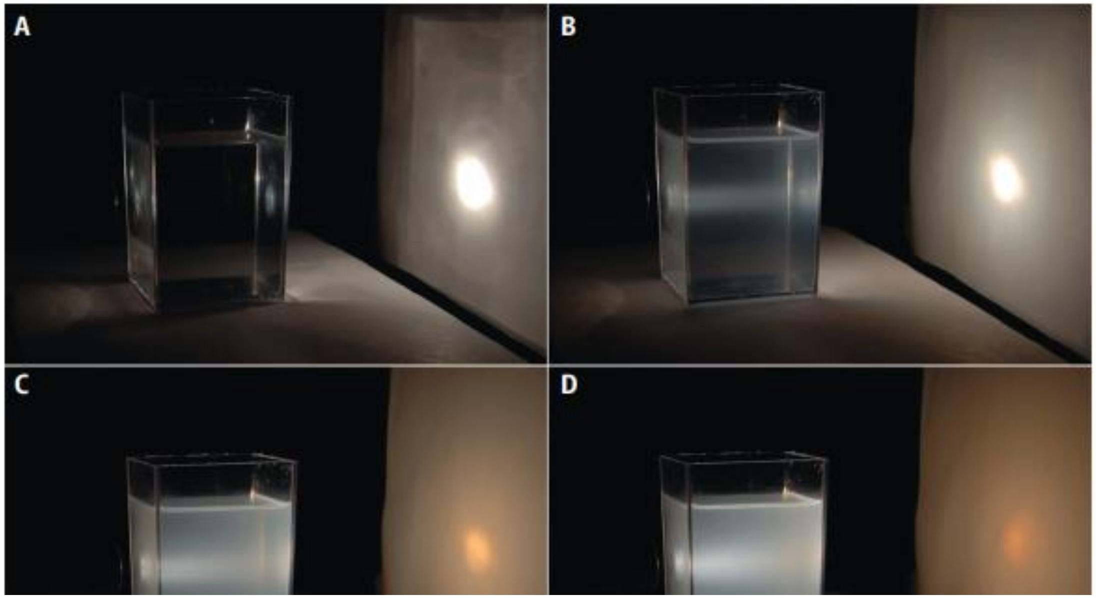
IBI* SERIES WINNER

An Inquiry-Based Curriculum for Nonmajors

Light, Sight, and Rainbows, the IBI prize-winning module, provides questions for exploring simple atmospheric phenomena.

David P. Jackson,[1†] Priscilla W. Laws,[1] Scott V. Franklin[2]

Only 28% of the U.S. adult population is considered scientifically literate. Although this is the second highest among 35 developed countries, a fact attributed to postsecondary science requirements (*1*), it should not be considered satisfactory, and improvement is critical to our future. A trend of many U.S. colleges and universities is to offer courses for nonmajors that cover a wide range of material via lectures, with few opportunities for students to engage in hands-on learning. This is particularly disturbing given that "a growing body of science educators has found that students' attitudes toward science, their motivation for learning, and their conceptual development … can all be enhanced by engagement in real scientific



Over 50 *Science* papers have been annotated and are ready for use in the classroom

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A collection of annotated research papers and accompanying teaching materials

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Biology
05/30/2014

Can DNA Enhance Your Look?

Fine Tuning of Craniofacial Morphology by Distant-Acting Enhancers. Attanasio et al.

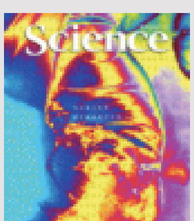
We're all familiar the adage that no two faces are alike. But, how is this tremendous amount of variation possible? Using genetic tools and three-dimensional imaging, this paper makes the case that...

Geology
04/25/2014

Quake, Rattle, and Roll

Enhanced Remote Earthquake Triggering at Fluid-Injection Sites in the Midwestern United States. van der Elst et al

One predictable feature of earthquakes is that they are completely unpredictable. Or are they? Scientists are beginning to collect data indicating that a range of human activity, including hydraulic fracturing, can induce earthquakes. How is this...



Do Clouds Need Passports?

Dust and Biological Aerosols from the Sahara and Asia Influence Precipitation in the Western U.S. Creamean *et al.*

Have you ever stopped to look at the clouds moving across the sky? How did they get there? And, where do they go after they finish dropping precipitation onto the land below them? Aerosol particles, either dust or biological, have an...

WHAT IS THIS?

Welcome to Science in the Classroom, a collection of annotated research papers and accompanying teaching materials designed to show students how science continues to advance.

About SitC

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Science Education Portal

An open-access website to know

http://portal.scienceintheclassroom.org

Science Education Portal

A collection of freely available education content published by Science

Science In The Classroom

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Highlights

Active learning: The twilight of Chem 101?

Making business students science-savvy

Convergence Between Science and Environmental Education

SPREADING THE SPIRIT OF SCIENCE

Strategy 2, partnerships:

Why everything depends on scientists getting involved

- It is much easier to teach science poorly, as the memorization of science facts, than to teach science well.

- Most current teachers are uncomfortable when students ask questions for which the teacher is unprepared.

- A stable and consistent external scientific community is therefore needed to support both schools and school systems for the many years that it will take to create outstanding school science education.

The Amazing Power of Local Science-Education Partnerships

- Scientists are urgently needed to support teachers.

- And scientists have a great deal to learn from outstanding teachers of children age 5 to 18 that will improve our own teaching.

Volunteer programs at my university, UCSF

Each year:

- **Active in 90% of San Francisco schools**
- **Benefit ~21,000 students**
  - 40% of SFUSD K-12 Student Population
- **Involve >350 Teachers and > 250 UCSF Volunteers**
- **Scientist volunteers contribute >10,000 hours**

UCSF University of California San Francisco

SCIENCE & HEALTH EDUCATION PARTNERSHIP UNIVERSITY OF CALIFORNIA · SAN FRANCISCO

When scientists partner with teachers, they also discover how poorly most school systems are run

And they come to realize that **“experienced, effective teachers are a vastly underutilized resource in education systems… perhaps the only resource that can truly create the change and improvements that students and teachers deserve.”**

Science magazine, January 15, 2016

EDITORIAL

Empowering great teachers

Long ago, U.S. business learned the benefits of constantly soliciting advice from workers on the shop floor by studying the startling success of the Japanese automobile industry. But the vast majority of U.S. school districts have remained hierarchical operations that ignore the wisdom available from their best classroom teachers. After decades of failed top-down solutions, now is the time to create a massive national movement that empowers and deeply respects our teachers. Scientists and science teachers can lead the way.

Producing an effective system of education is an extremely complex endeavor. Yet despite this complexity, U.S. policy-makers have been employing one simplistic top-down solution after another in attempts to improve schools. The most recent fiasco has been the high-stakes test-based accountability introduced by the federal government's No Child Left Behind Act of 2001. Against the advice of experts, the nation has even been mistreating teachers by grading them according to the annual test gains of their

"...now is the time to create a..national movement that empowers...our teachers."

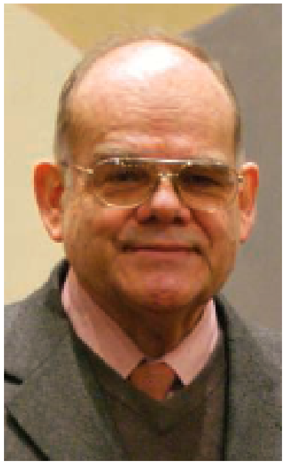
logic, while sorting, analyzing, and critiquing information. A skilled, experienced teacher creates appropriate challenges for each student, constantly suggesting ideas and connections to follow. A wise friend, with decades of leadership experience in my local public school system, is convinced that "experienced, effective teachers are a vastly underutilized resource in education systems...perhaps the only resource that can truly create the change and improvements that students and teachers deserve." But such teachers are rarely used appropriately, and they can even be resented by school system bureaucracies.

Launching an effective national movement to empower teachers will require casting a wide net to select specific strategies. Such an effort should begin by seeking advice from the best teachers. This can be done immediately for science, where an appropriate set of networks already exists. The organizations that oversee these networks would then form a consortium to select, and strongly advocate for, a small set of specific policies. Collaborations will need to

Bruce Alberts is the Chancellor's Leadership Chair in Biochemistry and Biophysics for Science and Education at the University of California, San Francisco, CA, and emeritus editor-in-chief of Science. *E-mail: Bruce.Alberts@ucsf.edu*

Scientists cooperating to catalyze a worldwide effort

EDITORIAL

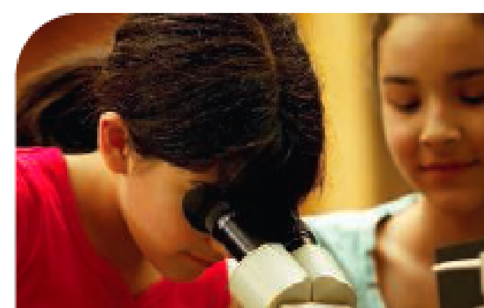


Jorge E. Allende is vice president for research at the University of Chile, coordinator of the IAP Science Education Program, and a former president of the Chilean Academy of Sciences.

Academies Active in Education

SUSTAINABLE SOCIOECONOMIC AND CULTURAL DEVELOPMENT REQUIRES NATIONS WITH A citizenry that understands science, shares its values, and uses scientific critical thinking. This can best be attained through science education that is based on inquiry, an approach that reproduces in the classroom the learning process of scientists: formulating questions, doing experiments, collecting and comparing data, reaching conclusions, and extrapolating these findings to more general situations. The Program for International Student Assessment, an international organization of industrialized nations, measures the extent to which 15-year-olds can identify scientific issues, explain phenomena scientifically, and use scientific evidence to draw conclusions. The results, made public earlier this year (http://nces.ed.gov/surveys/pisa), reveal that all developing countries and many industrial ones, including the United States, are failing to prepare their children adequately for life in the modern world. Leading scientists of each nation, acting through their national science academies, are working together to change this state of affairs.

In 1985, the U.S. National Academy of Sciences and the Smithsonian Institution established the National Science Resources Center, an organization that has helped to spread inquiry-based science education to nearly 20% of U.S. school districts. About 10 years later, across the Atlantic, the French Academy of Sciences engaged France's Ministry of Education with its "La Main à la Pâte" program, which today extends to most primary schools in France. The Swedish and Australian Academies similarly began major pro-



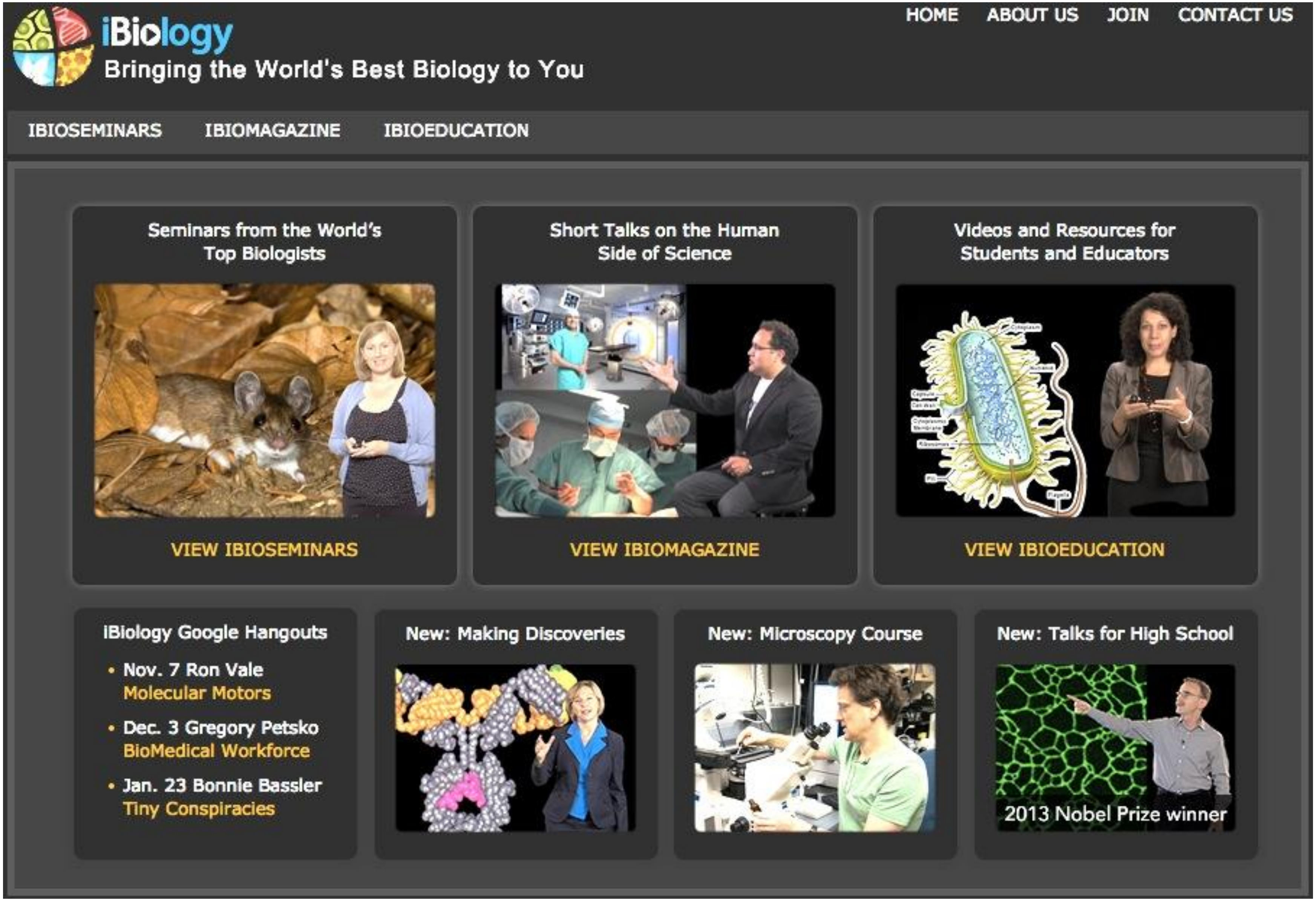
SPREADING THE SPIRIT OF SCIENCE

Strategy 3, promoting scientific knowledge as a "public good":

This requires both free Web-based knowledge resources and the availability of inexpensive bandwidth for all universities.

One attempt to spread good science

www.iBiology.org



For students, includes my short talk on "The Importance of Failure"

The hybrid Open Access/Open Archive publishing model at PNAS

- **Immediately free to everyone in 139 developing nations.**
- **Free after 6 months everywhere else.**

SPREADING THE SPIRIT OF SCIENCE

<u>Strategy 4, empowering our best young scientists:</u>

They are much more likely to be effective "ambassadors for science" than we are -- and they tweet and use Facebook!

An important tool for strengthening science – both in each nation and across the globe – is the formation of "**Young Academies**"

The first Young Academy was formed in Germany in 1995. To date, **25 nations** have formed such academies.

And a Global Young Academy headquartered in Berlin works to support this new idea (www.globalyoungacademy.net).

Scotland

South Africa

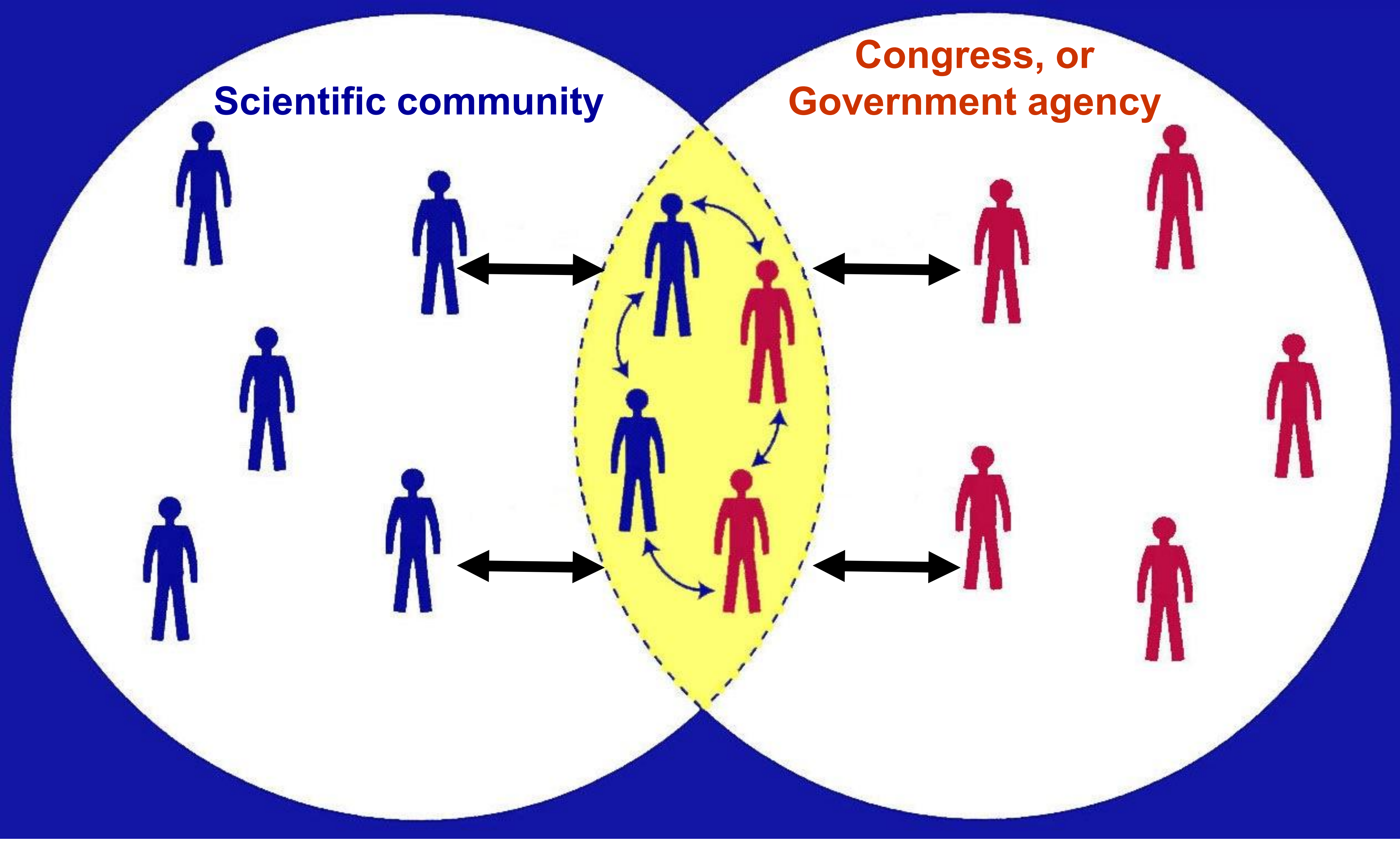
SPREADING THE SPIRIT OF SCIENCE

Strategy 5, developing scientists as connectors:

To spread science, we must **spread scientists**

Generating a scientific temper for our nations, requires scientifically trained people in all professions

- These individuals are invaluable for connecting the scientific community to the very different cultures of government, pre-college education, law, the media, business, etc.
- A model is the 45-year old "AAAS Science & Technology Fellowship" program that brings nearly 200 young scientists and engineers to work in Washington each year.



What I saw in Washington: strong interactions between individuals with a science background can bridge very different cultures

California state Legislature's Science and Technology Policy Fellows, year 1

California state Legislature's Science and Technology Policy Fellows

To date, 6 classes of these fellows have finished their one-year terms.

When the first 10 fellows were initially offered to the Legislature, **it was hard to find places that wanted them.**

After this first year, attitudes changed completely. In fact, about half of the 60 graduates of this program have now been permanently hired in policy roles, 13 by the state Legislature

Both the Legislature's appreciation of scientists and its use of science for decision-making have dramatically improved!

TO SPREAD SCIENCE

We need to create **new career paths for PhD's**, recognizing the value of scientifically trained people in many professions

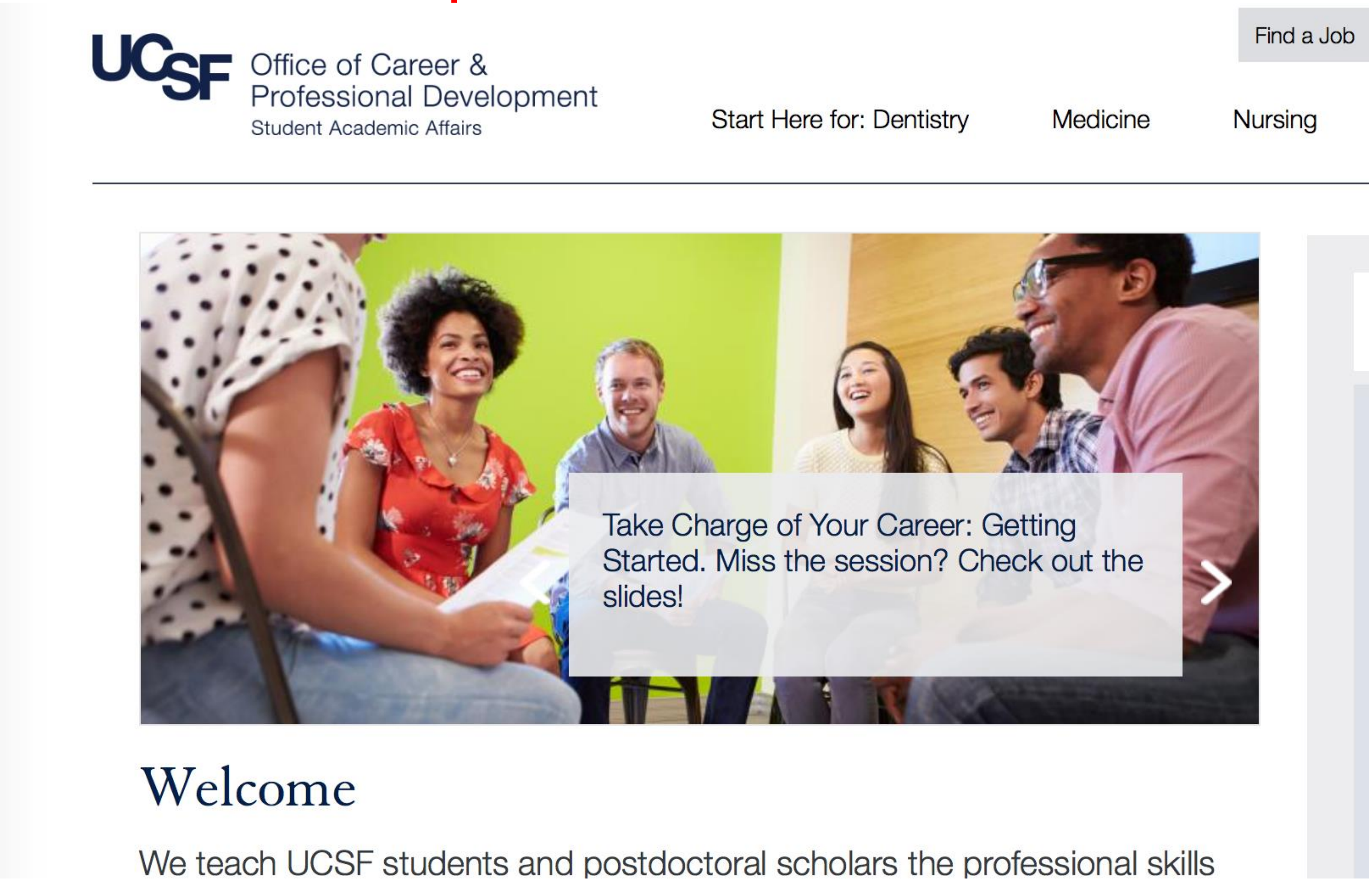
Important questions

- How can we *improve career development* for graduate students?

- When should career training & mentoring occur?

A leading effort in the USA

http://career.ucsf.edu/



Strategies at UCSF to improve career development for graduate students

1. **Individual Development Plan (IDP) online tool**
   – Used to guide and organize an individual's career development

2. **Graduate Student Internships for Career Exploration (GSICE)**
   – Offers hands-on experience in a non-academic research setting

What is an IDP?

It is an individual's *unique* annual plan to…

- **Consider long-term career goals**
  - Assessing self (skills, values, interests)
  - Choosing alternate long-term career goals
- **Set short-term, specific goals to help the individual work toward his/her long-term goals**
  - Exploring career options
  - Improving particular skills
  - Completing key projects
  - Getting relevant experience for the future
  - Building a network

Graduate Student Internships for Career Exploration (GSICE)

The Vision: Life science PhD students will have the support and opportunities to make free and informed career decisions by the end of graduate school.

How does GSICE facilitate career decision-making?

- **Mentorship**
  - Receive dedicated mentorship around exploring and pursuing non-traditional science careers
- **Professional skills training**
  - Develop the professional and transferable skills necessary for non-academic careers
- **Experiential learning**
  - **Three month, full-time internship outside of an academic research setting**

Types of internships chosen

- Science communication, education & policy internships
- Biotech research internships
- Intellectual property law internships
- Business relating to science internships

The desired impact of such strategies

1. **Change academic culture to value a diversity of career paths**
    1. "Non-traditional" careers become viewed as ***standard*** career paths that contribute greatly to the overall scientific enterprise.

    A broadening of what funding agencies consider to be a doctoral student's "successful outcome".

2. **Increase the attractiveness of advanced science education for all students**

A call to action: *PNAS*, April 2014

More goals than those discussed today

PERSPECTIVE

Rescuing US biomedical research from its systemic flaws

Bruce Alberts[a], Marc W. Kirschner[b], Shirley Tilghman[c,1], and Harold Varmus[d]

[a]Department of Biophysics and Biochemistry, University of California, San Francisco, CA 94158; [b]Department of Systems Biology, Harvard Medical School, Boston, MA 02115; [c]Department of Molecular Biology, Princeton University, Princeton, NJ 08540; and [d]National Cancer Institute, Bethesda, MD 20892

Edited by Inder M. Verma, The Salk Institute for Biological Studies, La Jolla, CA, and approved March 18, 2014 (received for review March 7, 2014)

The long-held but erroneous assumption of never-ending rapid growth in biomedical science has created an unsustainable hypercompetitive system that is discouraging even the most outstanding prospective students from entering our profession—and making it difficult for seasoned investigators to produce their best work. This is a recipe for long-term decline, and the problems cannot be solved with simplistic approaches. Instead, it is time to confront the dangers at hand and rethink some fundamental features of the US biomedical research ecosystem.

graduate education | postdoctoral education | federal funding | peer review

By many measures, the biological and medical sciences are in a golden age. That fact, which we celebrate, makes it all the more difficult to acknowledge that the current system contains systemic flaws that are threatening its future. A central flaw is the long-held assumption that the enterprise will constantly expand. As a result, there is now a severe imbalance between the dollars available for research and the still-growing

DNA sequencing, sophisticated imaging, structural biology, designer chemistry, and computational biology—has led to impressive advances in medicine and fueled a vibrant pharmaceutical and biotechnology sector.

In the context of such progress, it is remarkable that even the most successful scientists and most promising trainees are increasingly pessimistic about the future of their chosen career. Based on ex-

doubling of the NIH budget ended, the demands for research dollars grew much faster than the supply. The demands were fueled in large part by incentives for institutional expansion, by the rapid growth of the scientific workforce, and by rising costs of research. Further slowdowns in federal funding, caused by the Great Recession of 2008 and by the budget sequestration that followed in 2013, have significantly exacer-

Launching a **"Rescuing Biomedical Research"** movement by expanding the "Gang of 4" to 16


Shirley Tilghman


Marc Kirchner


Harold Varmus


Nancy Andrews


Judith Kimble


Freeman Hrabowski


Daniel Colón-Ramos


Jessica Polka

http://rescuingbiomedicalresearch.org

RESCUING BIOMEDICAL RESEARCH

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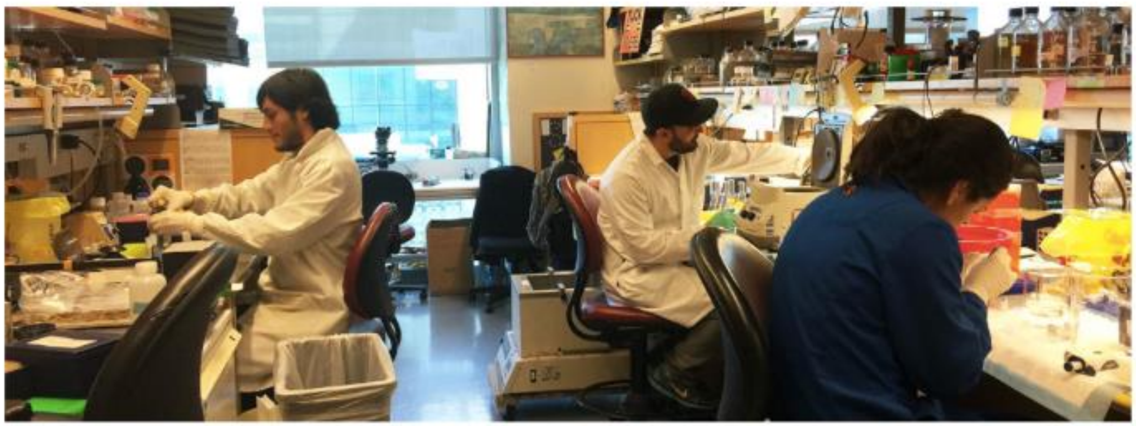

"…doing nothing is not an option. The stakes are enormous …"

Opinion: Addressing systemic problems in the biomedical research enterprise, PNAS, 2/17/2015

This website is designed to collect and organize input for solutions to problems such as those addressed in the April 2014 PNAS article entitled *Rescuing US biomedical research from its systemic flaws*, whose major points are briefly outlined here. Overseen by a Steering Committee that includes Nancy Andrews, Mary Beckerle, Jeremy Berg, Daniel Colón-Ramos, Ron Daniels, Rush Holt, Freeman Hrabowski, Tony Hyman, Judith Kimble, Jessica Polka, Joan Reede and Ron Vale — in addition to ourselves, the website seeks to organize, and begin to prioritize, the

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See upcoming events, or submit an event to be listed >>

IBIOLOGY VIDEOS: THE BIOMEDICAL WORKFORCE

View full-size movie at iBiology.org >>

View iBiology Video Series: The Future of the Biomedical Workforce >>

“Science knows no country..

Knowledge belongs to humanity..

It’s the torch that illuminates the world.”

Louis Pasteur